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PROBLEMS AND PROGRESS IN PLANT PATHOLOGY

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I. INTRODUCTION

It may be assumed, I trust, that I am doing the expected thing in choosing the topic of this address from my own field, phytopathology. If, however, justification is asked, the answer is clear. Plant pathology is simply a phase of botany. Practically all progress to date in its scientific development is owing to botanists. The rapid increase in numbers of those engaged upon work in this branch of botanical science has, however, naturally crystallized certain tendencies to segregation, giving us our independent Phytopathological Society with its separate program and its own journal. While this segregation is, in my judgment, the natural and wholesome result of progress, it creates problems and embodies danger to both parties. To the parent group, these lie in the loss of close association, heretofore had with some of its virile younger members; to the younger branch, there is the even more serious danger in passing from the critical and standardizing influence of the general Botanical Society dominated by maturer minds and broader ideals.

If we accept as true the statement of one year ago by Dr. Farlow[2] that America is today surpassing other nations in the study and applications of plant pathology, perhaps the first phase of biological science where this can be asserted, all will agree that much credit for this is

[1] Address of the retiring President of the Botanical Society of America, read at the Atlanta meeting, Dec. 31, 1913.

[2] Farlow, W. G. The change from the old to the new botany in the United States. Science, N. S. **37**: 79. 1913.

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due to the fact that our methods, ideals and leadership have come directly from botanical circles. Now that these relations are becoming less intimate, the responsibility rests upon both parties to see that by conscious effort we keep in closest touch; that the dangers of mutual loss from segregation be minimized to the utmost.

I have chosen the combination title, Problems and Progress, because of the necessary relationship of these two ideas. There may, indeed, be difference of opinion as to the relative stage of scientific progress in plant pathology, as compared with other branches of botany. There must, however, be general agreement as to the relatively great increase in activity in this field in the last two decades. Activity is the gage of life, and fullness of life should be the best criterion of progress. But we all recognize that whether or not activity or life in any scientific field does measure progress depends upon whether or not action is directed toward the solution of fundamental problems.

Let us with this in mind review the progress in phytopathology, trying to define and delimit some of the chief problems as they have successively arisen and to decide in how far they have been solved.

II. The Problem of Parasitism

Practical-minded men have faced the problems of disease in plants since plant culture began and those more scientifically minded have, of course, speculated or investigated in the matter. But it will profit us little to go back much more than a century for inquiry into either their definition of the problems or their progress in the solution. When Count Re, of Italy (1807),[3] following the lead of the Tyrolese von Zallinger (1773), attempted an account of what was known about plant diseases, practical or scientific, the result was largely barren because he had no conception of the meaning of parasitism. Little was known about the fungi and less about their host relations. Schweinitz, Persoon and Fries soon laid the secure foundations for mycological nomenclature and species descriptions, secure because based on keen observations and critical comparisons. But they had no concern with plant pathology and their contemporaries who had were star-gazing with the nature philosophers. Thus Count Re's

[3] Re, Fillipo. Saggio teorico pratico sulle malattie delle piante. Veneziae. 1807. An English translation was published in Gardiner's Chronicle, 1849, p. 228.

work remained nearly half a century after it was published as a standard writing in plant pathology.[4]

It required the plague of the potato disease and the example of the Irish famine finally to focus attention upon the fundamental problem—the relation of the mildew to the sick potato plant, of the smut and rust fungi to the infected grain—the problem of parasitism. True, they had been phrasing the term parasite much as we do, but so long as most held that the so-called parasitic fungus originated through the transformation of the sap or the degeneration of the diseased host tissues there could be no real progress in plant pathology whether scientific or practical. To De Bary's master mind we owe the clear recognition of the parasitic relations of fungus and host plant,[5] and from his demonstration of this we date further progress.

But although De Bary's work has settled for all time that the parasite is an independent plant entering the host from without and feeding upon it to its destruction, we must not forget that the more fundamental problems of parasitism remain with us. In biology, the definition is always dangerous, and the more complete and finished the more the danger. De Bary's classification of all fungi as parasites and saprophytes, obligate and facultative, is so complete and satisfying that it is constantly misleading. De Bary thought as the mycologist with attention focused upon the fungus. The first concern of the pathologist must ever be with the host plant, and chiefly with the host plant under conditions of culture. He must constantly be alert to the fact that parasitism is not a fixed but a fluctuating relation, dependent as to its occurrence and degree upon a complex of conditions, and these involving the reactions of not one but two widely different organisms. Although the fact of parasitism was settled and the modern science of plant pathology securely based upon it, there has been no time since when phytopathologists realized as clearly as today the importance of the problems yet to be solved in this field. We have scarcely begun the study of the intimate relations of parasite and host, the conditions and results of parasitism.

[4] The editor of Gardiner's Chronicle (1849, p. 211) prefaces the translation of Re's work with the statement that "it is the best work within our knowledge" upon this subject.

[5] De Bary, A. Untersuchungen über die Brandpilze und die durch sie verursachten Krankheiten der Pflanzen mit Rücksicht auf das Getreide und andere Nutzpflanzen. 1853.

III. The Life-History Problems

The fact of parasitism accepted, the problem of the life history of the parasite at once presented itself to these early students. Kühn's work on grain infection by smut (1858) and De Bary's upon the life histories of the Peronosporales (1863) with proof of heteroecism of the rusts (1864–5) set the pace. In the retiring address of my predecessor,[6] we learned how Farlow brought the coals to this country which have kindled the fires of our best American research in mycological pathology.

It should remain the first concern of plant pathologists that this work be continued. Discoveries as to life histories of parasites are, in the long run, of more practical importance as fundamental for disease control than demonstrations with spray mixtures. The latter are usually transient contributions, the former permanent. It is, therefore, of good promise that the two life-history problems which first engaged De Bary's efforts, those of the grain rust and the potato fungus, are today held more open and are receiving more earnest attention than when De Bary died. It is well that the problem of the overwintering of the apple scab is no sooner settled by one investigator for one locality than it is opened by another, working in a different environment. Life history problems have so many variations and complexities that they must ever remain with us, and progress in their fuller solution will continue as one index to general progress in plant pathology.

It is fortunate that they are so well suited for thesis problems of graduate students, and we may hope that the traditions established in the laboratories of Farlow and Atkinson may be perpetuated as well in other institutions.

IV. The Culture Problems

While De Bary in Germany was laying the foundation of mycological morphology, Pasteur in France was doing a correspondingly important work on the side of physiology, dealing with the fundamentals of fermentation and nutrition. Following his initial efforts, the problem of the pure culture with yeasts and bacteria was promptly defined and solved. Bacteriology not only came quickly into existence, but soon became the most exact science of the biological group,

[6] Farlow, W. G. Loc. cit.

owing to the fact that in such pure cultures environmental conditions can be controlled to a degree unattainable with the higher organisms.

Brefeld's success in culturing the smuts directed attention to this new method in studying the fungous parasites. Although the methods were adapted from those of the bacteriologists their uses with fungi are somewhat different. With these it is not only the gain from exact handling in differentiating mixed infections and inoculating from pure cultures, but also in completing life history investigations. With the imperfect fungi and Pyrenomycetes the method is especially applicable and the recent work on Glomerella by Shear[7] and Edgerton[8] illustrates well its advantages. To this method *Phytophthora infestans* has at last yielded the clue to its complete life history,[9] although here as always the developments in the culture tube need to be checked by comparison with those in nature.

For culturing the plant pathogens the value of the solid over liquid media and of vegetable over animal extracts becomes increasingly evident with experience. Thus the merits of Clinton's oat agar which gave such important results with Phytophthora have again been shown by the development upon this medium in our laboratory of perithecia of the apple scab fungus in greater abundance and vigor than ever observed in nature.[10] It should be assumed that for all such fungi which develop part of their fruiting stages saprophytically we may perfect culture media and methods which will not only simulate but may improve on those of nature.

And even the so-called obligate parasites deserve attention, for we are not restricted to artificial or dead media in pure culture work. The living sterile tissues of the proper host may be secured for many parasites providing only the need is sufficient to justify the pains-

[7] Shear, C. L. and Wood, A. K. Studies of fungous parasites belonging to the genus Glomerella. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 252. 1913.

[8] Edgerton, C. W. Plus and minus strains in an Ascomycete. Science, N. S. **35**: 151. 1912; also paper read at this Atlanta meeting.

[9] See Jones, L. R. and Giddings, N. J. Studies of the potato fungus. Science, N. S. **39**: 271. 1909. See also, ibid. **30**: 813, 1909; **31**: 752, 1910. Clinton, G. P. Oospores of potato blight. Science, N. S. **33**: 744, 1911; Conn. Agr. Exp. Sta. Rept. 1909–10: 753. Jones, Giddings and Lutman. Investigations of the potato fungus. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 245. 1912. Pethybridge, G. H. On pure cultures of Phytophthora infestans De Bary and the development of oospores. Sci. Proc. Royal Dublin Soc. **13**: 556. 1913.

[10] See abstract of paper by F. R. Jones: "Perithecia in cultures of Venturia inaequalis." Phytopathology **4**: 52. 1914.

taking. This of course, is easy with many interior tissues of fleshy parts, while for various other plants the seedlings may be grown from sterile seeds. It would seem that the problem of whether or not *Plasmodiophora brassicae* is the sole cause of club root of crucifers, or whether association is necessary with bacterial or other organisms, as has been suggested,[11] is a challenge to such increased skill in culture technique.

Finally, there is culturing upon the living host. Although this was the earliest method in vogue, and has yielded such gains especially in the hands of Arthur and others with rusts, yet the general applicability and importance of this practice in plant pathological investigations has not been fully realized. It is only thus that we can learn with exactness of related varietal or species susceptibility of hosts on the one hand, and of the occurrence of biological forms among parasites on the other—both things of paramount importance in plant pathology, scientific and economic. Success in such work is conditioned upon our ability to control and interpret environmental conditions. When the superiority of the greenhouse for such studies is more fully realized, we shall here work out the most of our fundamental problems, with the field plat as the place more important for verification than for investigation.

V. Bacteria in Relation to Plant Disease

The problems of bacteria in relation to plant disease naturally followed the advent of the pure culture method. While, from the American standpoint, this is the most important chapter in the development of modern plant pathology, it is at the same time, to us, the most familiar. The universally acknowledged world supremacy rests here, thanks to the high ideals and energetic—at times militant—leadership of him who two years ago was the honored president of this Society. I may only outline certain things in order to warn of dangers or suggest other problems.

Since the work of Burrill over forty years ago, no American worker has doubted the occurrence of bacterial diseases of plants. That Europeans were skeptical for a time was the natural consequence of too great reliance upon tradition and too great respect for authority. And as we grow older in the work in America we must realize that the

[11] Pinoy. Role des bactéries dans le developpement du Plasmodiophora brassicae. Compt. Rend. Soc. Biol. **58**: 1010. 1905.

traditions will soon be ours and that the paralyzing hand of authority will rest more heavily upon us. While in general we must follow its lead, and the "progressive" who breaks from the ranks must do so at his peril, let us keep alive to the need of progressiveness, and be patient with the man who challenges a traditional idea. Of course, every American recognizes fire blight of pear as the "classic" among bacterial diseases. But there may be blight which is not the bacterial fire blight. It is a wholesome thing, therefore, to have a challenge issued. It has been too easy, at least in horticultural circles of the west, to attribute all types of blighting of pear and apple trees to *Bacillus amylovorus*. One of the most reassuring things about the chestnut blight situation has been the fact that from the outset there have been those who must be converted. I have for years been convinced that American pathologists have relied too implicitly on authority in attributing all potato scab to one organism. Now that our so-called "Oospora scabies" seems to be of a bacterial nature[12] and the powdery scab of Europe is threatening if not invading our territory, we may hope for a revival of first hand investigations. And may we not be in danger of generalizing too broadly with reference to galls? The brilliancy and thoroughness of the recent work upon crown gall will almost inevitably encourage this in spite of the guarded and conservative statements made by the authors themselves.

The natural consequence of the general acceptance of the fact of bacterial diseases of plants, coupled with the lack of adequate training in bacteriological technique, led many in the early days to attribute numerous diseases to bacteria upon incomplete evidence. Nor was this confined to America. European literature, especially the French, has many such announcements. We need not criticize these too severely as to the past. It was natural and inevitable. But we are increasingly blameworthy if we continue either to publish carelessly or to accept the announcements of others without critical review. With the appearance of Smith's monographic work on Bacteria in Relation to Plant Diseases, any American at least, who describes a "new" bacterial disease of plants upon inadequate data should realize that he is committing an offence against the American profession.

This is not to imply that there are not plenty of bacterial diseases

[12] Cunningham, G. C. The relationship of *Oospora scabies* to the higher bacteria. Phytopathology **2**: 97. 1912.

of plants yet to be discovered, nor to discourage the search for these. It is rather to emphasize that there are other problems better worth while than the search for "new" diseases of minor economic importance. The simplicity of the bacteria in their relations to host and in the way they lend themselves to culture and infection stimulate the hope that through persistent intensive study of bacterial diseases we shall gain the clearer insight into those intimate relations of parasite and host which are fundamental to the science of plant pathology.

VI. The Relations of Parasite to Host and Environment

Although parasitology in relation to plant pathology dates from but little later than in animal pathology; and the relations involved would seem simpler than with the animal parasite, yet the fact remains that we are far behind the animal pathologists in understanding these relations. Some of the reasons for this are evident. The preeminent value of human life among the animals has focused attention upon human pathology. Even where attention has been given to the pathology of the lower animals, the students have as a rule approached the subject from the viewpoint of human pathology, and have been eager to apply to this any suggestions from comparative work on the lower forms. The result has been intensity and concentration of research upon the diseases of this one organism, man.

In plant pathology the natural tendency has been exactly the opposite. From the beginning the phytopathologist has included in his range of interests all the diseases of all plants known to him. The numbers of disease-inducing parasites is so enormous that it has consumed his professional energies simply to catalogue them. Concentration when attempted has been secured by narrowing one's interests within the parasitic group rather than within the host group.

I believe that we need to have, far more than heretofore, specialization by hosts in our phytopathological studies. Whether one is to probe deeper into problems of relations of environment to parasitism or into matters of predisposition and variations, either with host as to susceptibility or parasite as to its biological forms, attention should be focused long and intensively upon the one host. Experience has convinced me that one cannot understand the diseases of a cultivated plant like the potato, for example, except as he understands them in

relation not only to the normal physiology and morphology of the plant, but in relation to its history and its variations under culture. Progress requires that we have specialists on types of host plant as well as of parasite.

And, passing to the cellular relations of host and parasite, how little we know. The very simplicity of the plant's organization makes the pathological reactions harder to investigate than with the animal. In the plant the unit in the more fundamental pathological relations is not the organism but the cell, an object so minute as to make the study of the chemical interrelations highly difficult. We recognize the cell membrane as the first barrier to be overcome by the invader and we believe the cytolytic enzyme the first weapon in the attack. Yet, save with certain soft rot diseases, we know little that is definite about these enzymes in their action. We see evidence of other disturbing effects of parasite upon host cells, even in advance of actual invasion. Sometimes these are inhibitory or fatal, sometimes stimulating. But we have scarcely sufficient basis for a suggestion as to the nature of the agents involved. Such problems call for the combined skill of pathologist, physiologist, cytologist and chemist.

The variation in the occurrence of disease with environment is one of the commonest observations and a thing of the greatest practical moment. Yet how little progress we have made in understanding the factors. Climate and soil, both are composites of many variables, which in turn may react on either host or parasite. Why is it that Rhizoctonia diseases and Blattrollkrankheit of the potato claim so much attention in certain sections of the United States while in others pathologists are skeptical as to their existence? Why is it that the bacterial black leg of the potato develops so much worse in the south than in the north? Why is it that with the melon the Fusarium wilt is the scourge of the one section and the bacterial wilt of another? Why is it that the yellows disease of cabbage exterminates the crop under certain conditions and is of minor importance under others?

It would seem that here are problems to challenge the attention of every pathologist. Yet if one turns to them he is balked at the outset. We have inadequate data as yet regarding the occurrence and distribution of even the commonest economic diseases in the United States. Let us unite in urging that in the reorganization of the work now in progress in the Bureau of Plant Industry the entire attention of at least one expert pathologist be given to collecting and

analyzing such data, while all local pathologists pledge the undertaking continued support and cooperation. Coordinate with this, the local student of the special disease may make painstaking studies in field, greenhouse and culture chamber and in time delimit the effects of moisture, temperature, soil reaction and like factors upon each parasite and host.

The evidence is accumulating that the variations in relations between parasite and host which give us specialized races of parasites on one hand, and, on the other, gradations in disease-resistance of host, are of the greatest importance, whether scientific or practical. But we can as yet record little that helps us adequately to define the factors in the problems, much less to solve them.

As suggested before, these problems are at bottom physiological and of the most complex kind. The pathology of the past has been the work of the mycologist and the bacteriologist. That of the future must be increasingly dependent upon the physiologist; for what is pathology at bottom but abnormal physiology? Realizing how slow is progress upon the really fundamental problems in normal physiology and what dearth there is of workers adequately trained to grapple with them, we must be patient with ourselves and beg the patience of others when dealing thus with the abnormal. Perhaps our greatest hopes lie in the assurance that from now on increasing attention must and will be given to the training in physiology of those who are coming into the profession of plant pathology.

VII. The Non-Parasitic Disease

If the early workers in plant pathology erred in failing to recognize the importance of parasites as causal agents, the recent ones have gone to the other extreme.

The mycologist and the bacteriologist naturally bring to our attention even the minor parasitic maladies, the physiologist has as yet rarely come to our aid. It is only as one undertakes the comprehensive study of the maladies of a particular host that he realizes how few of the non-parasitic diseases have been listed.

Perhaps the peach, the tobacco and the potato are the only plants where the energies have been duly distributed between the investigations of parasitic and non-parasitic diseases. If anyone doubts that in these non-parasitic maladies we are dealing with specific

diseases having clearly defined symptoms which follow a regular course, let him grow China asters for a series of years in his garden and trace the course of aster yellows.[13] Here we have a malady as clearly characterized as a fungus rust or wilt disease; unknown, I believe, in Europe, but widespread in America, variable with season and locality, yet its etiology and pathology are entirely problematical.

But these are not problems to be undertaken lightly. Considering their inherent difficulties we may be thankful that such critical and persistent work has been given to certain types already, notably to peach yellows by Smith and to the mosaic disease of tobacco by Mayer, Beijerinck, Woods and others. It is encouraging to see that earnest attention is being given to certain apple maladies in different sections, especially the so-called "brown spot" or "bitter pit" in South Africa and Australia.[14]

Our encouragement will be greater, however, when we see the clear recognition of the fact that training in parasitology has only indirect value when it comes to such problems. The most evident need if we are to advance in the fundamentals of our research in this field of plant pathology is the reinforcement of our ranks with young men equipped with a high degree of special training in plant physiology grounded in organic chemistry, and ready to dedicate their services long and patiently to these physiological researches.

VIII. The Problems of Disease Control

Now you are expecting the statistics showing how many millions America is adding to her income by modern methods in disease control; but you have heard them often, so I need not repeat them; and they have much of truth in them. The yankee is practical, and the yankee mind dominates everywhere in America. Instead of boasting we rather owe ourselves this explanation—shall we say apology—when we point to the relative proportion of the space in American plant pathological publications given to the consideration of the spray pump and the disinfecting solution. How could it be otherwise? The millions spent by patent medicine advertisers have implanted firmly in the American mind the idea that each animal disease is a specific thing and for it there exists a specific remedy. It was, there-

[13] See Stone, G. E. and Smith, R. E. Mass. Agr. Exp. Sta. Bul. 79. 1902.

[14] McAlpine, D. Bitter pit investigations. First progress report. Melbourne. 1911–12.

fore, most lucky that when the professional "plant doctor" was introduced to the American rural constituency by the state experiment stations and national Department of Agriculture, he could step forward with Bordeaux mixture in one hand and formaldehyde in the other, two specifics which could at once be used and misused in a most amazing variety of cases without serious danger of loss of life or reputation. And just as these were becoming somewhat commonplace lime-sulfur was brought to our aid and with it the added enterprise of the American commercial advertiser.

Please do not misunderstand me. I recognize clearly that the highest duty in plant pathology is service, and that the chief aim in that service is to lessen loss from plant diseases. The only question is, how can we best serve to this end?

Perhaps as conditions have been, we could not at the outset have done much better. It was necessary first to educate the public as to the amount of their loss from plant diseases, as to the general nature of the parasites, and as to the great gains from the use of fungicides. In order to do this, the pathologist must familiarize himself with these things by repeated observations and trials and must contribute in turn to the education of the horticulturist, the agronomist and the agricultural press. This has taken time, in many cases nearly all of his time. But we may have satisfaction in the idea that it has been well done. No other country has had like service and in no other country has the agricultural public followed the teachings so fully.

It is important, however, for us to remember that this is the pioneer service, necessary and best at the outset; but that, as fast as conditions permit, we must be moving on to the attack on the more fundamental problems, to the performance of the more enduring service. The fundamental idea in plant disease control is prevention. It is surprising if one goes over the list how many diseases cannot be prevented by the use of fungicides. For the great classes of bacterial diseases, rusts and soil fungi, we must look to other measures. The three fundamental ideas which here deserve increased attention are sanitation, exclusion, disease resistance.

Spraying and seed treatments are only one part of sanitation in any case and have no part in many cases. Full data as to the life histories and modes of dissemination of causal organisms are more important fundamentals for improved sanitation than are further demonstrations with fungicides. The importance of fertilization,

cultivation and crop rotation in relation to sanitation, together with the destruction of diseased plant tissues and the checking of the carriers of disease germs, deserve more critical attention than they have received from plant pathologists as well as plant cultivators.

While America has for some time been the most advanced nation in controlling diseases by spraying, she has been one of the slowest to undertake plant disease exclusion. The plant quarantine act secured last year by the combined efforts of phytopathologists and entomologists marks, therefore, a most important forward step. The recent hearings relative to the potato disease quarantine, under this act, have served not only to emphasize its importance, both commercially and educationally, but also to point out important new duties for plant pathologists. In order wisely to administer such quarantine measures there must be international cooperation among phytopathologists in determining the occurrence and seriousness of plant diseases. But while we are thus beginning to guard our borders against potato wart and other dangerous foreign diseases, what are we doing within our own territory? For example, we know that there is an alfalfa disease (*Urophlyctis alfalfae*) similar to the black wart of potato in its nature and destructive possibilities, as yet apparently limited in its distribution to a few western alfalfa-growing sections.[15] No official steps have as yet been taken, so far as I know, to make exact determinations of its present distribution or to guard against its being carried to other places on seed. This would seem to be a national rather than a state function and the national plant disease survey already referred to would seem to be the logical first step. In this connection the plan outlined by Orton for official inspection and certification as to health of seed potatoes is highly significant.[16] I believe it must commend itself for adoption with various other crops as well. There is no other place more important for guarding the health of crops than at the source of seed.

And finally, there is the question of disease resistance and immunity. Of course, the idea is not new; observations upon the relative liability of varieties to disease come to us from early times. But the clearer conception of the possibilities in this respect of plant

[15] O'Gara, P. J. *Urophlyctis alfalfae*, a fungus disease of alfalfa. Science, N. S. **36**: 487. 1912.

[16] Presented in a paper before the Annual Meeting Wisconsin Potato Growers' Association, Nov. 20, 1913. To be printed in the Proceedings of this Association, which may be had from J. G. Milward, Sec'y., Madison, Wis.

improvement through breeding is recent. The relative success of the German and Scotch breeders in securing disease resisting potatoes is fully recognized.[17] The work started by Ward at Cambridge has raised our hopes relative to the possibilities of placing the studies of disease resistance on a scientific basis. The most stimulating results in America have dealt with resistance to soil fungi including Orton's work on cowpea, cotton and watermelon in the south and Bolley's on flax in Dakota. Such results as these and Norton's on asparagus rust resistance are to be regarded, not as final, but as merely suggestive of what I believe to be the most important future line of work in the control of plant disease, the breeding and selection of plants for local adaptation and disease resistance. If this is true then the fundamental problem deserving most serious consideration is, what constitutes disease-resistance? The difficulty of even defining the factors involved should not deter us from urging its importance and encouraging work upon it along all possible lines of attack.

IX. Conclusion

In conclusion let us emphasize that, if progress in plant pathology is to continue as rapidly as we hope, those who are responsible for its direction should realize the limitations of the individual workman, and the necessity for division of the labors involved.

The demand today upon the American phytopathologist is almost equally urgent for four types of service: (1) college teaching, (2) extension teaching, (3) inspection, (4) research. In how far are these compatible?

The ideal college teacher must be an investigator, but until we have passed the present stage of rapid growth in our state colleges, nothing comparable to the proper proportions in the division of his energies between these fields is practicable. The duties of public adviser or extension service in plant pathology may not be wholly incompatible with college teaching or station research, although at times seriously distracting. I am, however, convinced that in such matters the professional plant pathologist may in general wisely delegate the responsibility to act as spokesman to his associates in horticulture and agronomy. The nature of a disease and its mode of control once settled, the application of control measures becomes

[17] See Stuart, Wm. Disease resistance of potatoes. Vt. Agr. Exp. Sta. Bul. 122. 1906.

simply one factor in the complex of cultural operations for the execution of which the above departments become responsible.

Plant disease surveys, inspection and quarantine service belong in still another class and deserve the attention of experts in plant pathology. But back of all these must stand the investigator, with time and faculties kept free for his fundamental work; for research is the most exacting of all taskmasters. While no one realizes more keenly than do I the present impracticability, in general, of restricting our responsibilities along any such clean cut lines, nevertheless I am convinced that it is only as we clearly define these ideals and approach more nearly their realization that we are to secure the best results. It is encouraging, therefore, that these responsibilities are being divided in an increasing number of state institutions and that the proposed reorganization in the United States Department of Agriculture follows similar lines, differentiating research at least from the other fields of work.

If in this overlong discussion I have taxed your patience by emphasizing more the problems than the progress in plant pathology, it has been with a two-fold purpose. On the one hand, I have hoped thus to win your continued charity toward the plant pathologist, in view of the complexity of the problems which he must meet, administratively as well as scientifically. On the other, I have wished to urge your continued cooperation along the two lines: first, in training young men for the profession,—the best training our botanical institutions can give, with increasing attention to physiology; and second, in sharing, in the future as in the past, in the responsibility for focusing attention upon the fundamental problems and fixing standards by which rightly to measure progress toward their solution.

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